Technology Developments Integrating a Space Network Communications Testbed
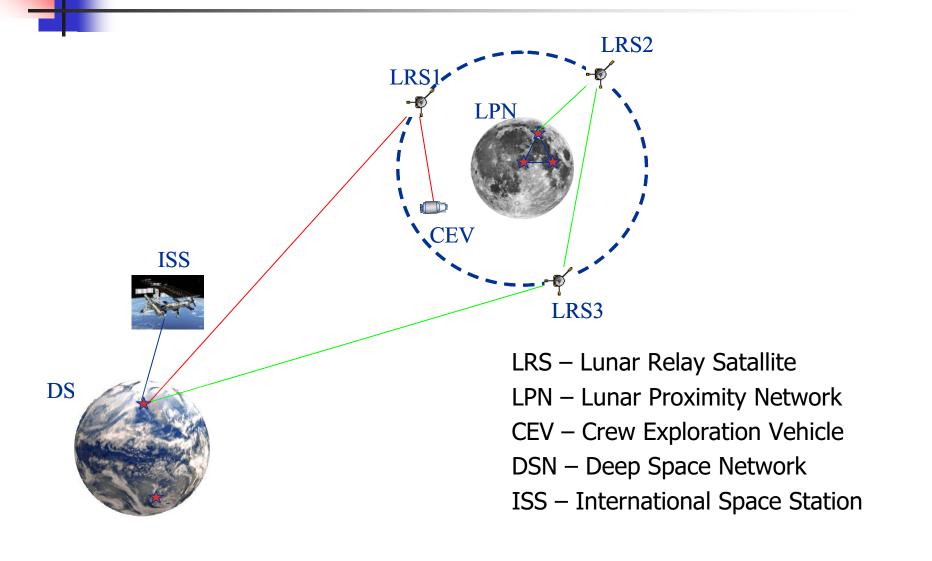
SpaceOps (June-22-2006)

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Future of Exploration Missions: Lunar Network Scenario

LRS2

LRS1

LPN

LRS3

CEV

ISS

DS

LRS – Lunar Relay Satallite

LPN – Lunar Proximity Network

CEV – Crew Exploration Vehicle

DSN – Deep Space Network

ISS – International Space Station

Space Communications Testbed: Objectives and Benefits

- Low cost method to validate communication architectures
- Detailed testing & performance evaluation of:
  - Space & ground networks
  - Client software applications
  - End-to-end communication involving real & emulated equipment

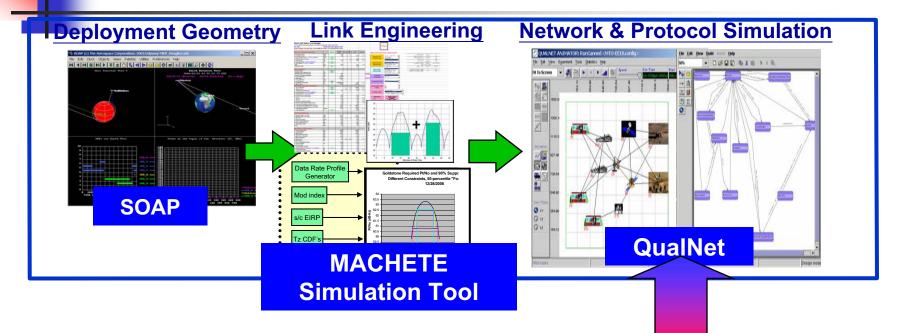# Space Communications Testbed: Objectives and Benefits (cont.)

- Flexible platform to evaluate technologies

- Validation & refinement of space network architecture requirements

- Analyze risks associated with communication architecture designs
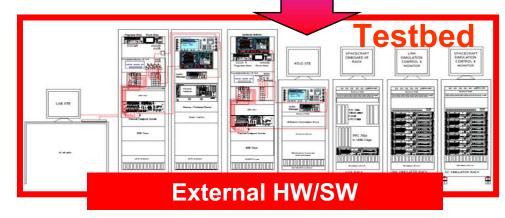
- Testing system interoperability

What We Did

- **Partitioned system responsibilities among the participating groups**
- **Designed system architecture**
  - Defined interfaces for testbed components
  - Developed simulation scenario
- **Constructed & tested initial prototype**
  - Integrated MACHETE (network simulator) into testbed

Integration of MACHETE and Testbed

Deployment Geometry

Link Engineering

Network & Protocol Simulation

SOAP

Data Rate Profile Generator

Mod index

s/c EIRP

Tz CDF's

Goldstone Required Pt/No and 90% Suppo
Different Constraints, 50-percentile "Fo
12/28/2006

MACHETE Simulation Tool

QualNet

Testbed

External HW/SW

MACHETE – Multi-mission Advanced Communications Hybrid Environment for Test and Evaluation

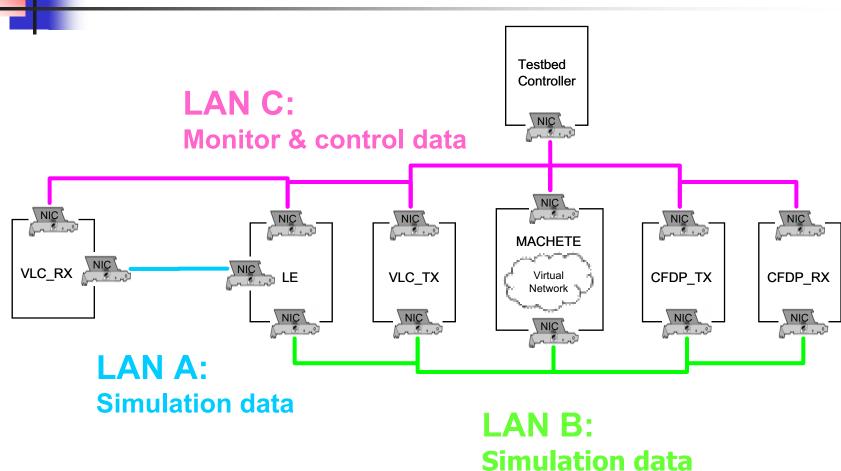# Two ways to integrate

MACHETE External Data Interfaces

- Transport layer: TCP-bridge [JPL, Scalable Networks Inc.]
    - Socket Connections
- Network layer: IP Network Emulator (IPNE) [Scalable Networks Inc.]
    - IP Packet Capture with "libpcap"

IPNE or TCP-bridge?

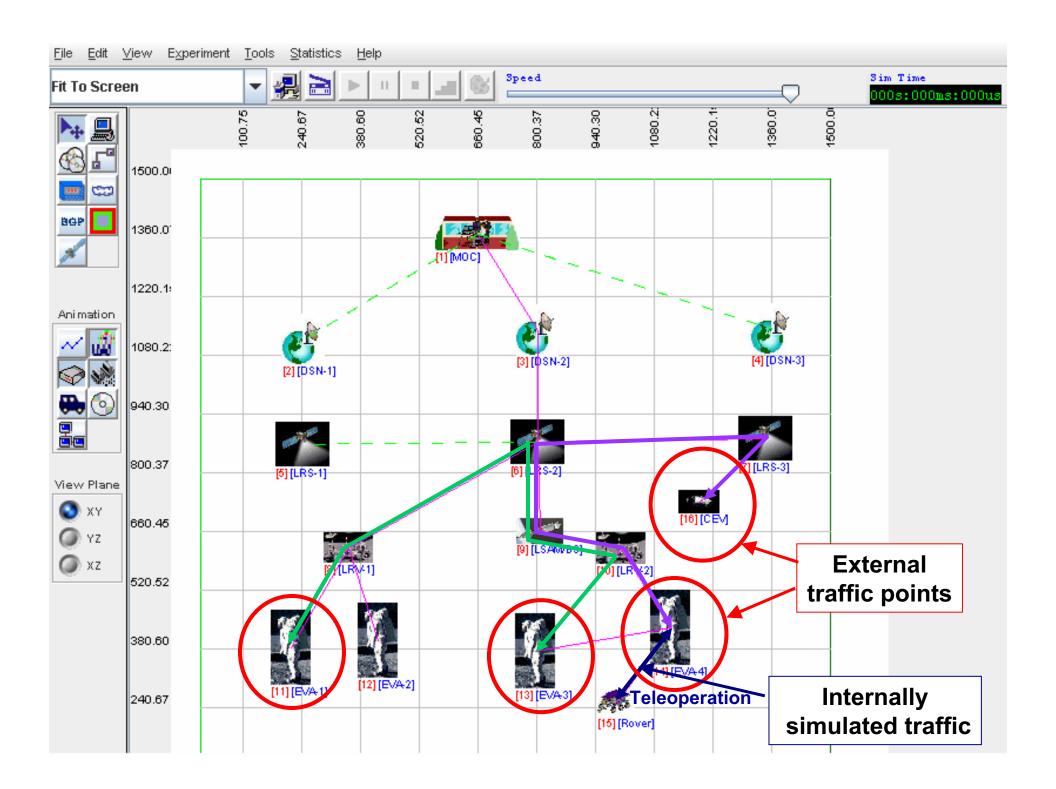| Feature	IPNE (with NAT)	TCP Bridge
Application Compatibility	Works with any applications that can communicate via TCP/UDP over IP.	Application data must be formatted for the custom bridging protocol.
Reliable Data Capture	No, since IP transmission is considered best-effort and not all packets are guaranteed to be sniffed.	Yes, since TCP supports reliable transmission.
Flexibility / Scalability	Can accommodate almost any type of testbed network topology.	Limited in how the testbed network can be setup. The number of external sources is limited to the network bandwidth.
Ease To Setup Network Testbed	Complex	Relatively simpler

Space Communications Testbed Block Diagram

Monitor & Control Messaging

External components can control MACHETE remotely through web-services:

- Currently support:
  - Start/Stop
  - Request run-time simulation statistics

Lessons Learned

- Testbed equipment performance limitations
    - With the IPNE interface, packet loss may occur due to the unreliable nature of IP
    - Hardware performance (CPU, NIC, RAM, etc)
    - Software performance (libpcap, QualNet, OS, etc)

- Testbed behaviors and characteristics can unintentionally influence simulation results, e.g.
    - Increased latency
    - Packet loss
    - Throughput degradation

IPNE Interface Performance Measurement

- We measured end-to-end effective bandwidth with IPerf
  - With MACHETE, we observed throughput degradation at 10 Mbps.
  - Without MACHETE, throughput degradation occurs at 70 Mbps
- The use of MACHETE places a constraint on what you can simulate.

Lessons Learned (cont.)

- Synchronization Issues
  - IPNE does not synchronize IP packet flow between testbed components with simulation time
    - Simulation results are non-repeatable
  - Interfacing at the transport layer can provide synchronization with metadata

Lessons Learned (cont.)

- **Tradeoff between IP and TCP interface**
  - TCP:
    - Require fine granularity; reproducible results
    - Smaller/simpler testbeds; require socket interface
  - IP:
    - Can tolerate "some" unintentional effects; do not require reproducible results
    - More flexibility in testbed topology; works with off-the-shelf Internet applications

Conclusion & Future work

- Must match the capabilities of the testbed with the simulation studies and analysis objectives
- Future work
  - Further characterize MACHETE performance limitations
  - Extend web services M&C capabilities, e.g. pause/resume and simulation parameter modifications